

WHAT IS CLAIMED IS:

1. An EGR-gas flow rate estimation apparatus for an internal combustion engine which has an exhaust circulation pipe connected between an exhaust passage and an intake passage, and an EGR control valve interposed in the exhaust circulation pipe and having a throttle portion for controlling flow rate of EGR gas flowing through the exhaust circulation pipe, the EGR-gas flow rate estimation apparatus comprising:

upstream-gas-pressure obtaining means for obtaining, as an upstream-side gas pressure, a pressure of EGR gas on the upstream side of the EGR control valve;

downstream-gas-pressure obtaining means for obtaining, as a downstream-side gas pressure, a pressure of EGR gas on the downstream side of the EGR control valve;

provisional-EGR-gas-flow-rate estimation means for estimating, as a provisional EGR gas flow rate, a flow rate of EGR gas passing through the EGR control valve, by use of a general formula which represents a flow rate of a compressible fluid passing through a throttle portion on the basis of an upstream pressure of the compressible fluid at a point immediately before the throttle portion and a downstream pressure of the compressible fluid at a point immediately after the throttle portion, the provisional-EGR-gas-flow-rate estimation means employing the obtained upstream-side gas pressure as the upstream pressure of the compressible fluid in the general formula, and the obtained downstream-side gas pressure as the downstream pressure of the compressible fluid in the general formula; and

EGR-gas flow rate estimation means for estimating the flow rate of

EGR gas flowing from the exhaust circulation pipe into the intake passage, by correcting an error which is contained in the estimated provisional EGR gas flow rate and which is caused by pipe friction between the exhaust circulation pipe and the EGR gas.

2. An EGR-gas flow rate estimation apparatus for an internal combustion engine according to claim 1, wherein

the upstream-gas-pressure obtaining means is configured to obtain, as the upstream-side gas pressure, a pressure of gas in the exhaust passage to which the exhaust circulation pipe is connected; and

the downstream-gas-pressure obtaining means is configured to obtain, as the downstream-side gas pressure, a pressure of gas in the intake passage to which the exhaust circulation pipe is connected.

3. An EGR-gas flow rate estimation apparatus for an internal combustion engine according to claim 2, wherein the EGR-gas flow rate estimation means is configured to calculate a correction value on the basis of a difference between the obtained upstream-side gas pressure and the obtained downstream-side gas pressure, and correct the error contained in the provisional EGR gas flow rate by use of the correction value.

4. An EGR-gas flow rate estimation apparatus for an internal combustion engine according to claim 3, wherein

the provisional-EGR-gas-flow-rate estimation means is configured to estimate the provisional EGR gas flow rate G_{egr0} on the basis of the following general formula:

$$G_{egr0} = A_{egr} \cdot (2 \cdot P_{ex} \cdot \rho_a)^{1/2} \cdot \Phi$$

$$\Phi = ((\kappa/(\kappa-1)) \cdot ((P_b/P_{ex})^{2/\kappa} - (P_b/P_{ex})^{(1+1/\kappa)}))^{1/2}$$

where P_{ex} represents the obtained upstream-side gas pressure, P_b represents the obtained downstream-side gas pressure, A_{egr} represents an effective opening area of the throttle portion, ρ_a represents a density of EGR gas at an upstream point immediately before the throttle portion, and κ represents a specific heat ratio of EGR gas; and

the EGR-gas flow rate estimation means is configured to obtain the correction value dP_{gain} in such a manner that the correction value increases toward 1 as the differential pressure ($P_{ex} - P_b$) increases, and estimate the flow rate G_{egr} of EGR gas flowing into the intake passage, by multiplying the provisional EGR gas flow rate G_{egr0} by the correction value dP_{gain} .